Ber. Ohara Inst. landw. Boil., Okayama Univ. 20 : 11～18 (1991)

CHANGES IN CONCENTRATION OF CADMIUM, ZINC AND IRON IN GLUTINOUS AND NON-GLUTINOUS RICE FOR CADMIUM SULFIDE WITH OR WITHOUT CALCIUM CARBONATE

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There have been many reports on the decrease of metal absorption by rice plants, through the application of calcium carbonate[5] or phosphate[12, 17] or silicate[14] to soil polluted with cadmium[1, 3, 4, 9, 13, 16]. However, these experiments have been performed with concentrations close to the lethal levels of rice plants.

In this experiment we have used the highest concentrations reported for treatment with CdS. CdS is considered as an insoluble salt, but the Cd content in rice grains after application of CdS in soil reached up to 2.11 μg/g in non-glutinous and 2.44 μg/g in glutinous rice at 10,000 ppm Cd in soil.

In this paper, the effect of calcium carbonate on the metal content of glutinous and non-glutinous rice grain was investigated up to the level of 10,000 ppm Cd in soil in the form of CdS.

MATERIALS AND METHODS

The nominal concentrations of CdS were 0,5,15,50,150,500,1500, 3000,5000,10,000 ppm Cd in soil. The pot size was 1/2,000 are and the 350 g per 10 kg dry alluvial soil. The pH value of soil ranged from 5.7-5.9 in controlled soil and around 6.6 in soil with $CaCO_3$ added.

Rice plants, *Oryza sativa* L. and *Oryza sativa* gluticum were planted from July to October for about 17 weeks. Every pot contained 5 g ammonium sulfate, 43 g calcium phosphate, and 1.4 g potassium sulfate, and received tap water containing < 0.01 ppm Cd to maintain good plant growth. After harvest, the rice samples were digested with HNO_3-$HClO_4$ (2 : 1v/v) solution for the determination of Cd, Zn, Fe with atomic absorption using the DDTC-MIBK extracting methods. Control soil contained heavy metals as follows: Cd 0.31 μg/g, Zn 144

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Received November 30, 1990

μg/g, Pb 34 μg/g, Cu 41 μg/g in dry matter. The chemical composition[15] of non-glutinous and glutinous rice in 100 g dry matter is as follows: protein 7.4 g, 7.6 g; sugar 72.5 g, 72.0 g; fiber 1.0 g, 1.2 g; Ca 10 mg, 10 mg; Na 3 mg, 3 mg; P 300 mg, 200 mg; Fe 1.1 mg, 1.1 mg; water 15.5 g, 15.5 g, and Calories (cal.) 33.7, 22.6, respectively.

RESULTS AND DISCUSSION

1. *Growth indices of rice plant with or without $CaCO_3$*

Figure 1 shows the relationship between yields of non-glutinous

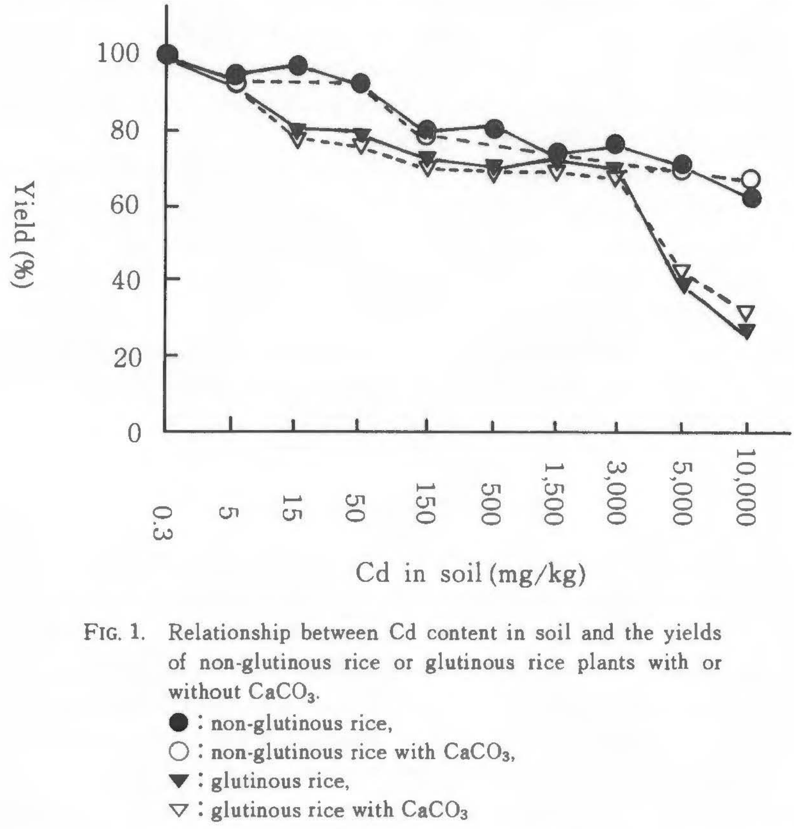

FIG. 1. Relationship between Cd content in soil and the yields of non-glutinous rice or glutinous rice plants with or without $CaCO_3$.
● : non-glutinous rice,
○ : non-glutinous rice with $CaCO_3$,
▼ : glutinous rice,
▽ : glutinous rice with $CaCO_3$

and glutinous rice and the cadmium concentration in soil. Table 1 shows the correlation coefficients between these growth indices as well as the Cd concentration in soil. Most of the growth indices decreased with the increase in the Cd concentration in soil except for the number of ears of glutinous rice in the $CdS + CaCO_3$ group. A significant difference in some growth indices of rice between the group treated with only CdS and group where $CaCO_3$ was added (Table 2).

The stem length, the weight of stem, and the number of ears of

TABLE 1. Correlation coefficients between the growth indices of non-glutinous rice and glutinous rice and Cd concentrations in soil with or without $CaCO_3$. (n=8)

	Treatment	a)	b)	c)	d)	e)	f)	g)
A	CdS alone	-0.862**	-0.703*	-0.860**	-0.678*	-0.769**	-0.854**	-0.782**
	CdS+$CaCO_3$	-0.912***	-0.966**	-0.918***	-0.789**	-0.742**	-0.214	-0.774**
B	CdS alone	-0.747*	-0.647*	-0.849***	-0.759**	-0.879***	-0.585	-0.929***
	CdS+$CaCO_3$	-0.715**	-0.621*	-0.830***	-0.734**	-0.862**	-0.577	-0.902***

* : $p<0.1$, ** : $p<0.05$, *** : $p<0.01$,
A : Non-glutinous rice plant, B : Glutinous rice plant,
a) : Length of stem, b) : Weight of stem, c) : Length of root, d) : Weight of root,
e) : Weight of rice grain, f) : Number of ears, g) : Weight of whole body

TABLE 2. T values (Student's t-test) for the significant differences of the various growth indices of non-glutinous rice and glutinous rice between the CdS alone and CdS+$CaCO_3$ group.

rice variety	a)	b)	c)	d)	e)	f)	g)
A	-0.51***	-2.98**	-0.86	-0.70	0.37	3.49***	-0.88
B	-4.81***	-2.55**	-0.80	-0.68	0.29	3.08**	-0.83

** : $p<0.05$, *** : $p<0.01$,
A : non-glutinous rice plants, B : Glutinous rice plants,
a) : Length of stem, b) : Weight of stem, c) : Length of roots, d) : Weight of roots,
e) : Weight of rice grains, f) : Number of ear, g) : Weight of whole body

non-glutinous rice significantly increased with the addition of $CaCO_3$[5]. The weight of rice grains slightly increased with the addition of $CaCO_3$.

2. *Cadmium concentration of non-glutinous rice and glutinous rice*

The relationships between the Cd concentration in soil and the Cd content of both rice plants in the groups of Cd alone and Cd plus $CaCO_3$ are shown in Fig. 2. Table 3 show the respective correlation and the correlation coefficients between the Cd, Zn, and Fe content of soil and both variations of rice plants. Table 4 shows the significance of differences in Cd, Zn, and Fe concentration between non-glutinous rice and glutinous rice.

There was a positive correlation between the concentration of cadmium in soil and the cadmium in brown rice of both non-glutinous and glutinous rice plants. The maximum concentration of Cd in non-glutinous rice and glutinous rice was found to be 2.44 $\mu g/g$, and 2.11 $\mu g/g$ respectively, at the level of 10,000 ppm Cd in soil.

These values were in the same magnitude as in previous results, and much lower compared with the values for treatment with

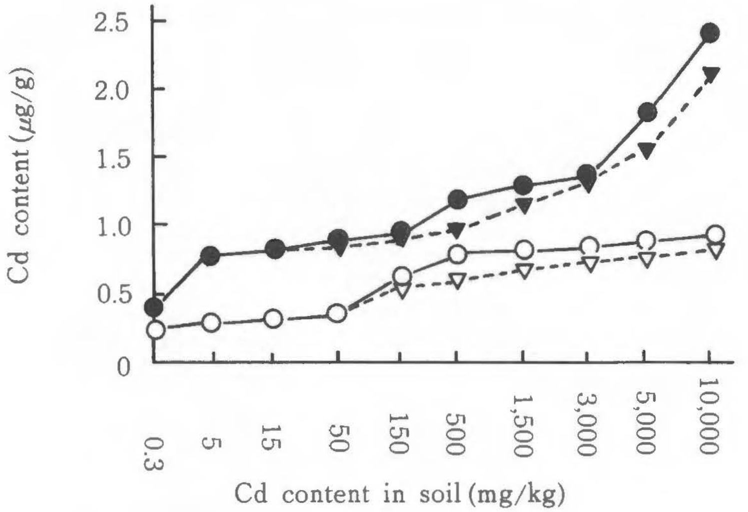

FIG. 2. Relationship between Cd content of soil and non-glutinous rice or glutinous rice with or without $CaCO_3$.
● : non-glutinous rice,
○ : non-glutinous rice with $CaCO_3$,
▼ : glutinous rice,
▽ : glutinous rice with $CaCO_3$

TABLE 3. Correlation coefficients and equations between Cd concentrations in non-glutinous and glutinous rice and Cd concentrations in soil with or without $CaCO_3$. (n=10)

Metal	(Cd in soil)-(Metal in rice)	Correlation coefficient	Correlation equation
Cd	(CdS, soil) - (A)	0.895***	Y= 0.161 logx+0.361
	(CdS+$CaCO_3$, soil)-(A)	0.966***	Y= 0.086 logx+0.164
	(CdS, soil) - (B)	0.889***	Y= 0.132 logx+0.402
	(CdS+$CaCO_3$, soil)-(B)	0.977***	Y= 0.069 logx+0.178
Zn	(CdS, soil) - (A)	-0.982***	Y=-1.147 logx+31.51
	(CdS+$CaCO_3$, soil)-(A)	-0.957***	Y=-1.042 logx-0.957
	(CdS, soil) - (B)	-0.949***	Y=-0.719 logx+31.96
	(CdS+$CaCO_3$, soil)-(B)	-0.918***	Y=-0.874 logx+34.00
Fe	(CdS, soil) - (A)	-0.960***	Y=-0.075 logx+0.767
	(CdS+$CaCO_3$, soil)-(A)	-0.991***	Y=-0.037 logx+0.663
	(CdS, soil) - (B)	-0.986***	Y=-0.070 logx+0.759
	(CdS+$CaCO_3$, soil)-(B)	-0.980***	Y=-0.048 logx+0.716
Yield (%)	(CdS, soil) - (A)	-0.950***	Y=-3.488 logx+101.6
	(CdS+$CaCO_3$, soil)-(A)	-0.974***	Y=-3.445 logx+100.1
	(CdS, soil) - (B)	-0.854***	Y=-5.673 logx+99.69
	(CdS+$CaCO_3$, soil)-(B)	-0.902***	Y=-5.376 logx+98.05

* : $p<0.1$, ** : $p<0.05$, *** : $p<0.01$,
A : Non-glutinous rice plant, B : Glutinous rice plant

TABLE 4. T values (Student's t-test) for the significant differences of the metal concentration of non-glutinous and glutinous rice between the Cd alone and Cd plus $CaCO_3$ groups. (n=10)

Metal	(CdS) - (CdS+$CaCO_3$)	t-values	Significant differences
Cd	A	4.90	* * *
	B	5.75	—
Zn	A	-0.97	—
	B	-3.88	* *
Fe	A	-1.71	—
	B	-3.05	* *
Yield	A	0.79	—
(%)	B	0.94	—

* * : $p<0.05$, * * * : $p<0.01$, — : no significant differences,
A : Non-glutinous rice, B : Glutinous rice,

$CdCl_2\ 2\frac{1}{2}H_2O$ or CdO[8].

The maximum concentration of cadmium in wheat grains was found to be 123.2 μg/g Cd at the critical levels of 1,500 ppm Cd in soil and as low as 57.5 μg/g Cd, when treated with $CaCO_3$[10].

3. *The concentration of Zn and Fe in rice grain*

Fig. 3 and 4 show the relationships between Cd concentration in

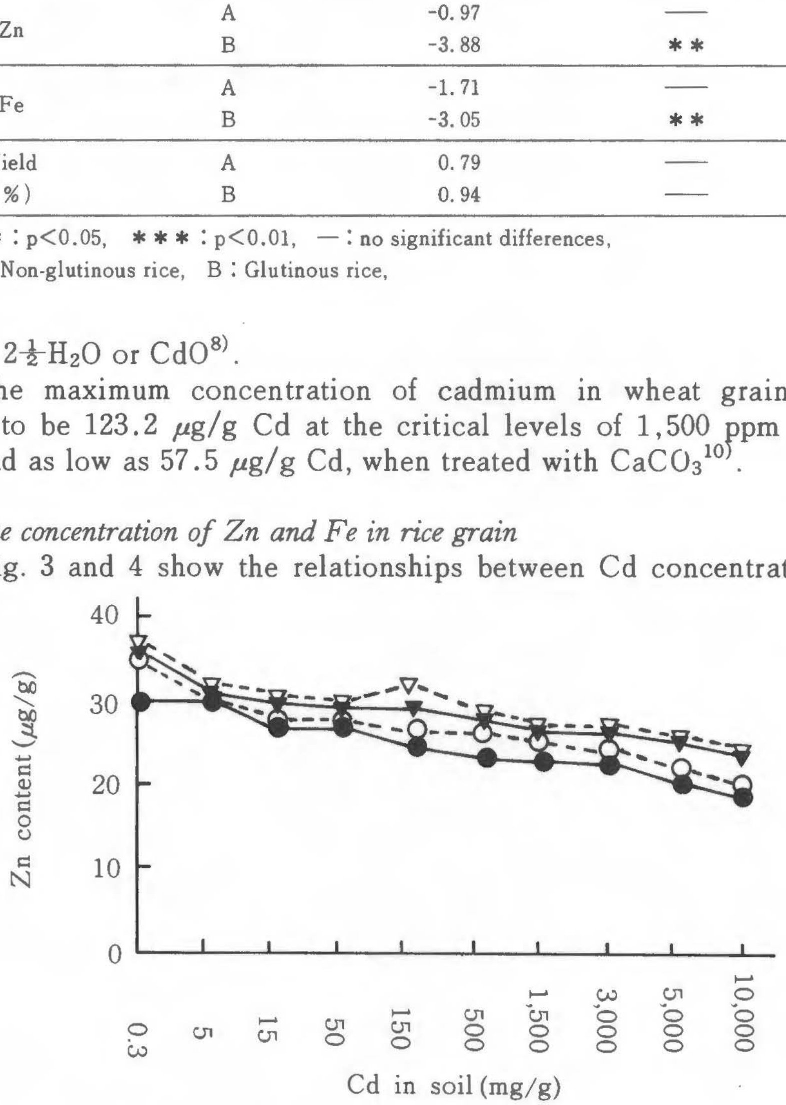

FIG. 3. Relationship between Zn content of soil and non-glutinous rice or glutinous rice with or without $CaCO_3$.
● : non-glutinous rice,
○ : non-glutinous rice with $CaCO_3$,
▼ : glutinous rice,
▽ : glutinous rice with $CaCO_3$

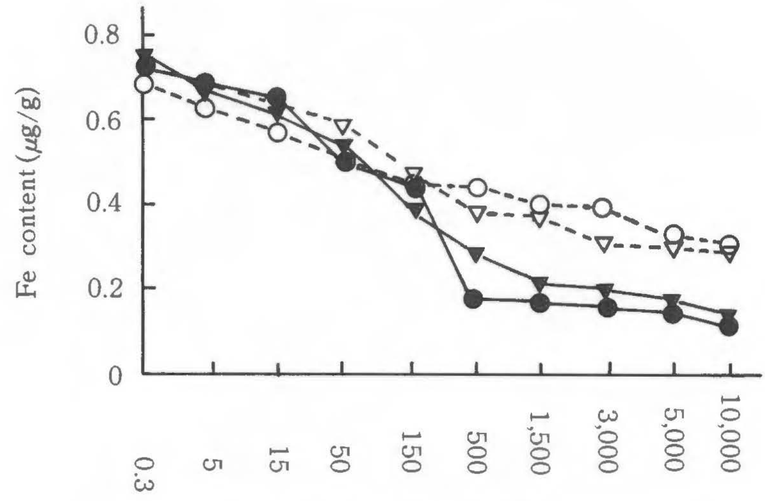

FIG. 4. Relatioship between Fe content of soil and non-glutinous rice or glutinous rice with or without $CaCO_3$.
● : non-glutinous rice,
○ : non-glutinous rice with $CaCO_3$,
▼ : glutinous rice,
▽ : glutinous rice with $CaCO_3$

soil and the Zn, Fe contents of both non-glutinous and glutinos rice plants when treated with Cd alone or with Cd plus $CaCO_3$, respectively. The zinc and iron concentration of both variations of rice plant tended to decrease with the increase in the Cd concentration in soil. A significant decrease in the Zn and Fe content of both non-glutinous and glutinos rice grains treated with only Cd or with the Cd plus $CaCO_3$ group was observed ($p<0.01$ for Zn, $p<0.05$ for Fe).

The solubility of Cd, Zn, and Fe decreased by increasing the pH value with the addition of $CaCO_3$. Cd became less soluble beyond the level of pH 6.5[5,11]. Cadmium also suppressed the uptake of zinc and iron in rice plant and wheat. Especially the concentration of iron and zinc in rice grain gradually decreased with the increase in the Cd content of soil.

Suppression of zinc and iron uptake suggested the incidence of cadmiuminduced metal element deficiencies in plants. Occurrence of chlorosis[2,5,6] in non-glutinous rice is more frequent than in glutinous rice ($p<0.01$).

It is less frequent in the presence of $CaCO_3$. The zinc concentration in non-glutinous rice is significantly higher than in glutinous rice ($p<0.01$), and slightly higher in the absence of $CaCO_3$.

The Fe concentration in both variations of rice plants was similar to the Zn concentration, had or through it was much lower than the Zn concentration. Therefore, antagonism was observed in the concentration of cadmium and zinc or iron in grain of both variations of rice plants[5, 8].

SUMMARY

The Cd content of glutinous (*Oryza sativa,* L.) and non-glutinous-rice (*Oryza sativa,* glutican) treated with CdS, an insoluble salt increased with the Cd content of soil, but the cadmium uptake was lower than in the case of CdO. Cadmium induced metal element deficiencies in rice plants, which were associated with the phenomenon of chlorosis and were alleviated with the application of calcium carbonate at an early stage of rice growth.

The Cd content of both variations of rice significantly decreased by the addition of $CaCO_3$. The Zn and Fe contents of plants decreased with the increase in the Cd content of soil.

Acknowledgements We thank Dr. J. Kobayashi, Dr. F. Morii, and Dr. M. Yagi for their valuable suggestions.

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